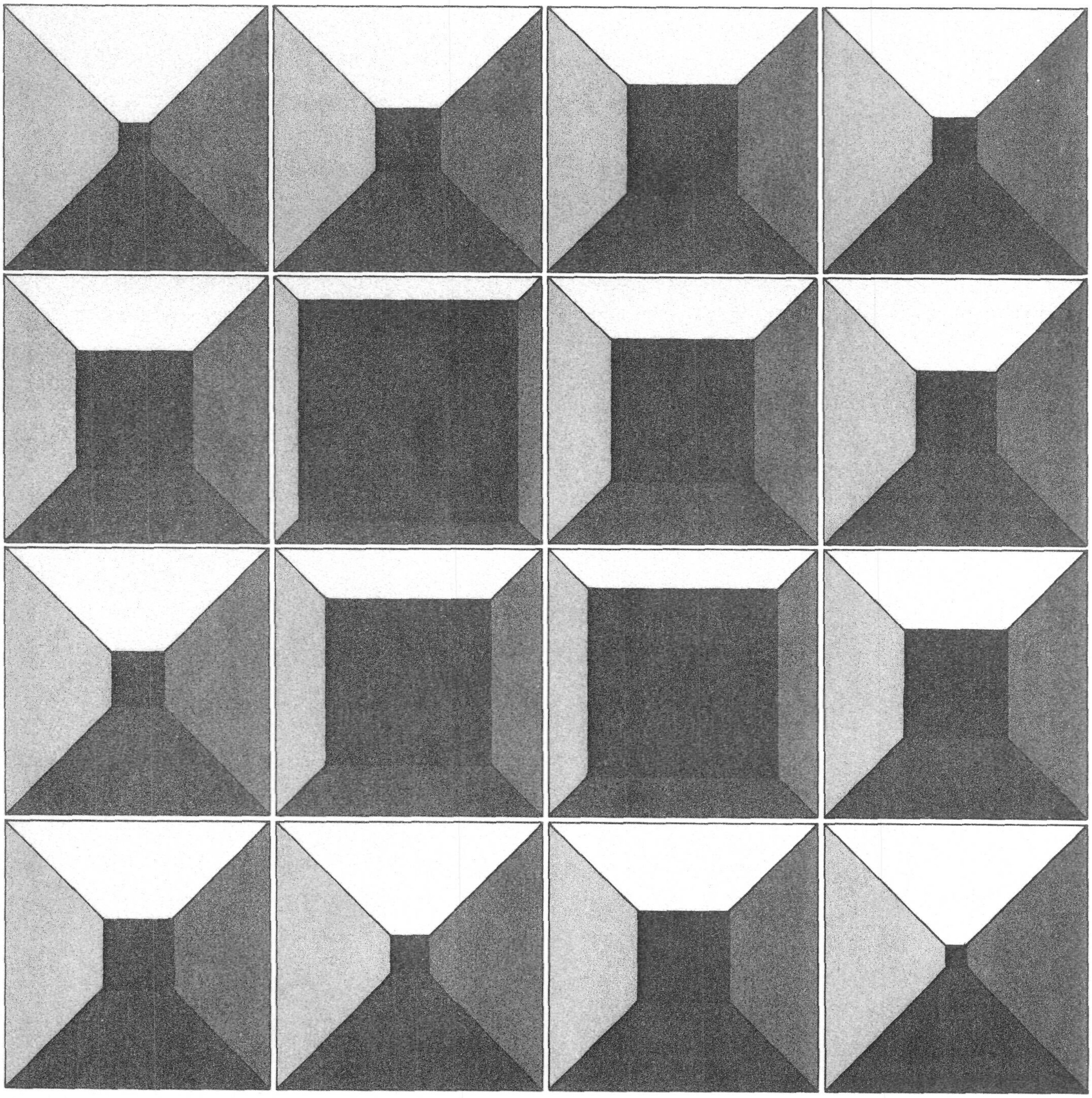
Financing Radioactive Waste Disposal

A CBO Study
September 1982

Congress of the United States
Congressional Budget Office



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NOTE

All cost estimates in this report are in fiscal year 1982 dollars unless otherwise noted. All costs are for fiscal years unless otherwise specified.

PREFACE

Radioactive waste, in the form of spent nuclear fuel, is now stored on electric utility sites in temporary facilities. The accumulation of these wastes is a significant source of concern to the utilities, their ratepayers, and the nuclear industry. Although the federal government is responsible for the ultimate disposal of these wastes, considerations of economic efficiency and fairness suggest that the costs incurred by the government in carrying out this responsibility should be borne by the recipients of the service--ultimately the users of nuclear electricity. The costs, however, are not likely to be a large addition to the price of electric service, even with serious cost overruns in the disposal program. This implies that, of all the complex issues surrounding radioactive waste disposal, financing the program should be the most tractable.

The most advanced, and perhaps sole, option for disposal of radioactive waste is burial in a geologic repository. The Department of Energy has developed a program for the construction and operation of two such repositories, which it estimates will cost $14.8 billion in fiscal year 1982 dollars. Since these wastes are a by-product of the generation of electricity using nuclear power, several proposals have been made to finance the program through a generation fee assessed on each kilowatt hour of electricity produced by civilian reactors. In response to a request by the House Committee on Interior and Insular Affairs, this report examines the level of such a fee required to finance the waste disposal program, and how such a fee would respond to changes in the costs and other aspects of the program.

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Alice M. Rivlin
Director

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SUMMARY

Radioactive waste, in the form of spent nuclear fuel, has been accumulating since the advent of the commercial reactor program for nuclear-powered electric utilities. Because this material is potentially dangerous to human health, it must be carefully and permanently sequestered from the biological environment. This is true whether the waste material is the spent reactor fuel itself or the residual waste by-products produced by extracting useful elements from the spent fuel. The federal government is responsible for the ultimate disposal of radioactive waste, but development of a final disposal program has been sporadic.

Because the nation's electric utilities currently store large amounts of radioactive spent fuel in on-site interim facilities, many nuclear power plants are running out of interim space--29 nuclear units in this decade--and those that do may be forced to shut down or ship the waste to other locations where additional on-site capacity is available.

In response to these problems, plans are under way to construct a series of geologic repositories for long-term waste burial. The Department of Energy (DOE) program analyzed in this paper calls for the construction of two repositories that would be ready for fuel loading in 1994 and 1999.[1] The DOE repository program also includes research and development, site selection, construction of a test facility, provision for payments to state and local governments in whose jurisdictions the repositories would be located, operation and maintenance of the repositories during their lives, and final decommissioning (shutting and sealing) of the two facilities. This entire program is estimated to cost $14.8 billion in fiscal year 1982 dollars if it proceeds on schedule and if the DOE cost estimates are correct.

Considerations of economic efficiency, fairness, and effective program management all suggest that the users of nuclear-generated electricity should pay for this disposal service. With regard to economic efficiency, internalizing the costs of waste disposal would cause consumers of nuclear electricity to pay the correct price for their consumption. This would provide incentives for the least-cost mix of capital and fuels in the electric

1. The DOE schedule has changed since this analysis was written. The current schedule calls for completion of the first two repositories in 1997 and 2002. This change does not affect the conclusions of this paper, however.

industry. As to fairness, simple justice would imply that electricity consumers, who receive the full benefits of nuclear-generated electricity, should pay the full costs. With regard to effective program management, fees paid by electricity consumers might prove a more stable source of program funding in a period of budgetary constraint.

FINANCING RADIOACTIVE WASTE DISPOSAL

In response to these concerns, legislation (passed by the Senate, S. 1662, and now being considered by the House) proposes that the waste disposal program be financed through a generation fee on each kilowatt hour of electricity generated by nuclear power. Calculation of the correct fee is complicated because the schedules of annual program costs and annual generation fee revenues are very different. While annual generation fee receipts are stable, annual program costs are relatively high early in the program (as the research and development and construction phases occur), low in the middle (as the repository is filled), and higher again when the repositories are decommissioned. If a fee were assessed to match the stream of annual costs, it would charge consumers of nuclear electricity early in the program a far higher price than would be charged later consumers for the same amount of electricity. An equitable self-financing program, therefore, must find some constant level (corrected for inflation) of generation fee that is sufficient to meet the program's total costs over its complete life.

A Waste Disposal Trust Fund

The asymmetry of annual program costs and revenues could be resolved through use of a trust fund to collect and disburse program revenues. In the program's early years, annual program costs will exceed generation fee revenues. During this phase the trust fund could borrow to meet its obligations. It would, of course, be responsible for interest payments on this borrowing. Once the repository is open and accepting waste, program costs will drop, and annual surpluses will occur. The trust fund would then retire its debt and invest its remaining surplus to earn interest (presumably through the purchase of government bonds).

Annual revenues from generation fees will cease when the last batches of fuel in the current program are withdrawn from their reactors. At this point, the surplus in the trust fund, together with the interest it has earned, must be large enough to cover the remaining program costs of interment of the last batches of waste and decommissioning the repositories. If a generation fee was set at the correct level, it would leave a surplus large enough to cover these final costs. Once the last dollar of the program costs has been paid, the trust fund should have a value of zero. If these conditions were met, the radioactive waste disposal program would be self-financing. Furthermore a correctly set fee should charge current and future electricity consumers the same price for the equal benefits. In this report, such a fee is termed an "optimal fee," that is, the fee that would be charged if the future were known perfectly.

EVALUATING THE GENERATION FEE

If the exact costs and scheduling of the radioactive waste disposal program were certain, then the calculation of the optimal fee would be complicated but unambiguous. But the world is not a certain place, and the history of the program to date suggests that the cost uncertainty normally associated with large, first-time engineering projects is compounded by difficult social and political questions, including licensing requirements for the repositories and the issue of their location. Thus, there is a reasonable probability that the optimal fee required to make the program self-financing will be larger than that suggested by the current DOE cost estimates. This raises two issues:

- How sensitive is the level of the optimal fee to changes in the assumptions underlying the program costs or the demand for repository services? and

- Who should bear the risk that the fees might have to be raised in the future in response to unforeseen cost increases?

Sources of Sensitivity in the Optimal Fee

Three major sources of sensitivity are analyzed in this report.

- The Level of Nuclear Generating Capacity. If a lower rate of growth in nuclear generating capacity is assumed, then the level of the optimal fee would increase since it would take longer to fill the repository, adding to the costs of its operation.

- Additions to the Current Definition of the Radioactive Waste Program. If other elements are added to the definition of the radioactive waste program, then the optimal fee would increase. Most probable potential additions include a Monitored Retrievable Storage facility (which would extend above-ground interim storage capabilities) and the government's assumption of responsibility for transportation of wastes from generation stations to the repository.

- Program Cost Overruns. If the waste disposal program experiences cost overruns, as is common to programs of this type, then the optimal fee level would increase significantly.

All of these potential changes would necessitate a higher level of the optimal generation fee. But two of them--changes in program definition and changes in the rate of growth in nuclear power--would not substantially change the fee required for a self-financing waste program. Under most reasonable assumptions regarding these two factors, the optimal fee would remain in the range of 1 percent of the cost of nuclear-powered electricity. But cost overruns would necessitate proportionate increases in the optimal fee level. Recent engineering studies suggest that cost overruns as high as 160 percent are plausible for initial projects of this type. If cost overruns of this magnitude occurred, they would require a parallel increase of 160 percent in the optimal fee.

The value of the optimal fee under a variety of assumptions is given in the Summary Table. If a high rate of nuclear growth occurs, then the optimal fee would be .483 mills per kilowatt hour. Under the other extreme assumption of very low nuclear growth, the fee would be .570 mills per kilowatt hour--a 20 percent increase, but still only about 1 percent of the cost of nuclear-powered electricity. For each of the four nuclear-growth scenarios analyzed in this report, the inclusion of transportation costs in the program also would lead to a 20 percent increase in the fee level, and the inclusion of a Monitored Retrievable Storage facility would add about 5 percent. Thus, these are not important sources of sensitivity in the optimal fee.

The optimal fee, however, would vary proportionately with cost overruns. A 40 percent cost overrun would increase the real level of the fee by 40 percent, and a 160 percent overrun would increase the fee by 160 percent. While this study does not predict such overruns and has not reviewed the methodology underlying DOE estimates, the history of comparable projects suggests that overruns of this magnitude cannot be ruled out.

These values for the optimal fee under cost overrun assumptions are oversimplified in one respect. They assume that the fee would be corrected for cost overruns at the onset of the program. It is more likely that the program would be well under way and into its construction phase before overruns could be gauged with any degree of accuracy. This raises the issue of risk. If cost overruns are not planned for, but do occur, then either the generation fees would have to be raised to recoup the overruns or the

SUMMARY TABLE. GENERATION FEE LEVEL REQUIRED TO CREATE A SELF-FINANCING REPOSITORY TRUST FUND, UNDER ALTERNATIVE ASSUMPTIONS, BY RATES OF NUCLEAR-POWER GROWTH (In mills per kilowatt hour, in fiscal year 1982 dollars)

Assumption	High Growth	Medium Growth	Low Growth	Very Low Growth
DOE Program Cost Estimates	.483	.517	.549	.570
Inclusion of Transportation Costs	.592	.633	.664	.669
Inclusion of a Monitored Retrievable Storage Facility	.506	.541	.577	.600
40 Percent Cost Overrun	.672	.718	.764	.792
160 Percent Cost Overrun	1.238	1.324	1.407	1.458

government would have to provide the additional funds. In this situation, current electricity consumers would be subsidized by future ones, since they would not have paid their "fair share." But if overruns are planned for yet do not occur, current consumers would have overpaid their share and would have subsidized future ones. Thus, the major issue concerning the setting of the generation fee is: who should bear the risk of substantial cost overruns in the radioactive waste disposal program?

Options for Assigning the Financial Risk

This report examines four approaches to assigning the risk of unanticipated cost increases in the waste program:

- Assign the Risk to Current Ratepayers. Current ratepayers would be forced to bear the risk by paying a fee higher than that calculated to be optimal, thus building into the trust fund assumptions regarding the amount of cost overruns.

- Assign the Risk to Future Ratepayers. Future ratepayers would be forced to bear the risk if an optimal generation fee were calculated using current DOE cost estimates that would have to be adjusted later should these estimates prove wrong.

- Assign the Risk to the Federal Government. The government could bear the risk by promising to meet any costs above those anticipated at the beginning of the program or some other announced level.

- Assign the Risk to Private Investors. A federal corporation could be chartered and licensed by the Nuclear Regulatory Commission to construct and operate the waste disposal repositories. In return for its profit, it would assume responsibility for any cost overruns or other unanticipated financial difficulties with the program.

Assign Risk to Current Ratepayers. Current ratepayers would absorb the risk by paying an initially higher fee. Two arguments can be made for setting the initial fee at a level higher than that warranted by the best current cost estimates. The first is that experience has shown such early estimates to be understated consistently. Hence, a higher initial fee would simply ratify that experience. Second, it can be argued that present electricity users have created the demand for nuclear power plants and have borne the other financial risks of nuclear power. These current electricity users, therefore, should also bear the financial risks of disposing of its wastes.

Three objections may be made to these arguments. First, it is not possible to know how high to raise the fee above current estimates; and indeed, current cost estimates presumably already include substantial margins for error. Second, the existence of a financial cushion might reduce the incentives for efficient program management, thus leading to self-fulfilling cost overruns. Third, future electricity users would also benefit from the same nuclear power plants that serve current users.

Assign Risk to Future Ratepayers. Future users of nuclear electricity would bear the risk if the fee were set at the current optimal level and adjusted upward as events develop. This has the advantage of making the best use of currently available information. But all the surprises would probably raise costs and result in future electricity consumers subsidizing current ones.

Assign Risk to the Government. Although considerations of efficiency and equity suggest that the radioactive waste disposal program should be entirely self-financing, rationales do exist for the federal government to assume the risk that program costs could escalate dramatically. For example, the government, as manager of the program, should bear some part of the responsibility for cost overruns and for the lack of progress that has characterized past efforts. Alternatively, the government could choose to subsidize nuclear energy by assuming some of the risk of cost overruns.

If the federal government decided to absorb cost increases above some stipulated level, the value of this subsidy could be estimated from the value of the trust fund at the end of the program. In the worst-case assumption of cost overruns of 160 percent, utilities would be guaranteed that the generation fee would not exceed the level premised on DOE base-case costs. The implicit subsidy, therefore, would be the present value of the trust fund deficit at the end of the program--that is, the amount of money that the government would have to put into a bank account now to cover this future deficit. This analysis estimates that under this worst case, the federal subsidy would have a present value between $11.5 billion and $12.6 billion, in fiscal year 1982 dollars. A more moderate assumption would have the government absorb costs above those that would raise the fee above some chosen level, say 1.0 mills per kilowatt hour. Under this case, the present value of the federal subsidy would range between $4.0 billion and $5.9 billion, again in 1982 dollars.

Assign Risk to the Private Sector. An alternative to assigning the cost overrun risk to the federal government would be to assign it to the private sector. The Nuclear Regulatory Commission could license a federally chartered corporation, which would exercise a monopoly franchise for waste disposal services, and set rates in the same fashion that the optimal fees are calculated in this report. In effect, the corporation would become a "waste disposal public utility." This approach might minimize real costs through more effective management, and would require the firm's stockholders and management to absorb the risk of cost overruns.

Such a corporation, however, would raise several difficulties. It might be difficult to find private firms interested in providing this service. Licensing requirements might be extraordinarily rigorous, and the liabilities incurred in the event of a major accident might be uninsurable. There is also the possibility that such a firm would fail. If it did, the federal government could end up assuming the responsibilities it had attempted to delegate to the private sector in the first place. And if the government assumed program management, it would either have to raise fees to cover costs or subsidize the program in order to honor the corporation's long-term contracts with utilities.

If neither of these two options--to assign risk to the government or to the private sector--was selected, the issue of risk would devolve on guessing how extensive cost overruns would be over the life of the program, and, in turn, whether to preempt their effects on the trust fund by charging a higher fee than warranted by the DOE base-case cost estimates. In essence, this would be a choice between assigning the risk to current or future ratepayers. Assigning the risk incorrectly could result in intergenerational subsidies in the order of $1.1 billion to $7.3 billion (in fiscal year 1982

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dollars), certainly a significant amount, but less than the level of comparable intergenerational transfers associated with other government programs (notably Social Security).

The foregoing analysis implies that special attention must be given to the engineering cost estimates of the program. Misestimating the project costs could lead to significant redistributions of income between current and future electricity ratepayers. While this analysis has not reviewed those cost estimates, the history of comparable first-time engineering projects of this scale suggests that the danger of significant cost escalation cannot be discounted.

CONCLUDING REMARKS

It is clear that an economically efficient, fair, and effective program for radioactive waste disposal would closely match the users of nuclear-generated electricity with the cost of the program. This analysis suggests that the fees covering these costs are not great--less than 1.5 mills per kilowatt hour, even with large cost overruns. By contrast, the average charge for residential customers of electricity in calendar year 1980 was about 54 mills per kilowatt hour. Regulations, such as the new source performance standards of the 1977 Clean Air Act Amendments raised electricity costs in calendar year 1980 by over 2.3 mills per kilowatt hour on a nationwide basis. In some areas of the country, compliance with the current new source performance standards would raise generating costs as much as 10 mills per kilowatt hour. Radioactive waste disposal fees are likely to be small by contrast.

This has two implications. First, it suggests that waste disposal fees are not likely to be decisive in the economics of nuclear power. Second, it suggests that financing may be a relatively minor issue among the many that surround radioactive waste disposal. Delays in establishing a beneficiary-financed program, however, would lead to the accumulation of spent fuel whose disposal has not been paid for. To the extent this occurs, it would exacerbate concerns with intergenerational fairness.

CHAPTER I. INTRODUCTION

The federal government is responsible for the ultimate disposal of radioactive waste, which is a by-product of nuclear-generated electricity and nuclear weapons production. Since the beginning of the commercial reactor program, nuclear electric utilities have been accumulating spent fuel which is stored in on-site interim facilities. (Military nuclear waste is treated separately.)

Many of these nuclear-powered utilities are now running out of interim storage space--as many as 29 in this decade--and those that do may be forced to shut down or ship the waste to other locations. Obviously, there is a growing need for a federal program to provide final disposal repositories. In response to this need, the Department of Energy (DOE) has proposed a program to construct two geological repositories for long-term waste burial.

The custodianship and disposal of radioactive waste, with its half-life of 10,000 years or more, reflects many concerns, chief among them human health, environmental protection, land use policy, energy policy, state versus federal authority, and the proliferation of capabilities to acquire nuclear weapons. This paper examines the problem from a different perspective: how the nation should pay for the interim storage and ultimate disposal of radioactive waste. Its underlying premise is that economic efficiency, fairness, and, indeed, the capabilities of the radioactive waste program itself will be improved to the extent that the final beneficiaries of the program--the consumers of nuclear-generated electricity--pay its costs, rather than the taxpayers at large. Specifically, this paper addresses the financing requirements of the waste disposal program proposed by DOE to construct two final repositories, scheduled to open in 1994 and 1999, at an estimated cost of $14.8 billion (in 1982 dollars).[1]

A BRIEF PRIMER ON RADIOACTIVE WASTE

Radioactive wastes are of primary concern because of their potential danger to human health and the environment. These wastes contain atoms

1. The DOE schedule has changed since this analysis was begun. The current schedule calls for opening the first two repositories in 1997 and 2002. This change does not affect the conclusions of this paper, however.

whose nuclei decay, emitting energized subatomic particles and electromagnetic radiation. When this radiation interacts with human tissue, or for that matter with any biological material, many molecules are damaged by the breaking of chemical bonds and by ionization, which produces yet further chemical change, producing cancer, genetic mutation, or death. High-level radioactive wastes can be divided into "fission products" and "actinides." For periods up to several hundred years, the dominant risk is from fission products--atoms of medium atomic weight formed by the fissioning of uranium and plutonium. These are principally strontium-90 and cesium-137, although numerous others are present. After roughly 700 years, fission products decay to less than one ten-millionth of their original activity and cease to be of practical concern.

Beyond several hundred years, the dominant source of radioactive hazard is the actinides: heavy atoms of actinium, thorium, uranium, plutonium, and the other "manmade" elements with atomic weights greater than uranium. These are quite toxic and decay relatively slowly, reaching the hazard level of the original uranium ore from which they were derived in about 10,000 years. Thus, the actinides require sequestering from the biological environment for times best measured in geological, rather than historical, terms.

Radioactive wastes are primarily the by-product of commercial nuclear power and nuclear defense activities. Small amounts are also generated through medical applications and other activities that use radioisotopes, but these wastes are relatively small in quantity and low in radioactivity. Hence, the issue is dominated by nuclear fuel and nuclear defense activities. While radioactive wastes are encountered at most stages of the nuclear fuel cycle, those of greatest potential concern are found in spent fuel. The spent fuel from military reactors is chemically reprocessed and the resulting waste stored in retrievable solid or liquid form at three federal installations: the Idaho National Engineering Laboratory near Idaho Falls, Idaho; the Savannah River Plant near Aiken, South Carolina; and the Hanford Reservation near Richland, Washington. Under current plans, these wastes would be immobilized in a solid material before disposal in stable geological formations.

The spent nuclear fuel from commercial reactors is stored temporarily at the reactor sites themselves.[2] These waste materials remain encapsuled

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2. Small amounts of reprocessed commercial waste remain at the site of a closed reprocessing plant at West Valley, New York. In addition, small amounts of commercial spent fuel are stored at West Valley and at another nonoperating reprocessing facility at Morris, Illinois.

in the original fuel assemblies, arrays of zircaloy-clad uranium fuel rods roughly 4 meters long and weighing from 150 to 650 kilograms, depending upon the reactor type. About 25 metric tons are discharged annually from each power reactor.

Once the spent fuel has been withdrawn from the reactor core and cooled in a storage pool on the reactor site, several options are available for its intermediate handling. First, the fuel could simply be stored on-site until a final repository becomes available. But the pools in which many reactors store used fuel are likely to be filled long before a repository could be ready to receive the spent fuel. This concern has motivated a search for other intermediate options: more compact storage of the spent fuel at the reactor site, or shipment to other commercial nuclear plants with more storage capacity or to a special storage site away from the reactor (commonly termed "away-from-reactor" facility, or AFR). Alternatively, the spent nuclear fuel could be "reprocessed"--dissolved in an acid bath, with the remaining uranium and plutonium fuels recycled for further use, and the radioactive wastes separated for final disposal. Although this method is sanctioned by the Reagan Administration, reprocessing is unlikely to become economic in the near future. Furthermore, it raises serious questions of safeguarding the plutonium from diversion to nuclear explosives.[3] Finally, a Monitored Retrievable Storage (MRS) facility has been proposed. The MRS would provide longer-term storage than the AFR, but not permanent disposal. It would preserve the spent fuel until such time as the cost of uranium ore made reprocessing economically attractive. After reprocessing, the wastes would be shipped to a repository for final disposal.

Numerous alternatives have been proposed for the ultimate disposal of nuclear waste--either as spent fuel or as a reprocessed solid. The most developed of these is interment in geological formations of great stability. Salt, basalt, and tuff are now under investigation. Under DOE plans, a repository would be in operation in the United States by 1994 (or 1997 as revised).

FINANCING RADIOACTIVE WASTE DISPOSAL: PRINCIPLES AND PRACTICE

The interim storage and eventual disposal of defense nuclear wastes is paid for by the taxpayers; this is appropriate since the public at large

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3. The Carter Administration banned reprocessing as part of its nonproliferation policy.

benefits from defense with nuclear weapons. Although many debate the appropriateness of funding these defense programs through the Department of Energy rather than the Department of Defense, the choice of federal entity does not affect the principle that the government should pay. As long as defense programs pay their full share of any disposal facilities used in common with commercial waste, this principle would not be violated. This full share would include common as well as facility-specific costs. Therefore, this paper deals with financing the disposal of commercial waste from nuclear power plants, for which a method to charge users has not been determined.

For commercial radioactive waste, considerations of economic efficiency, fairness, and effective program management all suggest that the users of nuclear electricity should pay for the services that they receive from the government. These fees could be placed in a special trust fund established to pay for the two permanent waste repositories, as discussed in Chapter III. With regard to economic efficiency, internalizing the cost of waste disposal into the price of electricity would help assure that the economically correct amount of electricity is used and that the correct mix of generating stations are built. As to fairness, the principle that the recipient of a service should bear the cost of providing it (in the absence of an intended subsidy) is well-established. With regard to program effectiveness, charging for waste disposal services might lead utilities and their customers to assume an interest in the efficient management of the program. Perhaps more important, it also might provide a more stable source of funding than is possible under current budgetary constraints.

But the difficult issues in financing radioactive waste disposal do not derive from the abstract merits of user charges. Rather they arise from the way the user charge system would be implemented. If the world were a more certain place, implementation would be straightforward. The tasks of the disposal program and its attendant costs could be specified with precision and assigned to the users of nuclear electricity in direct proportion to the benefits they receive. But the world is not a certain place, and the history of the radioactive waste program suggests that the cost uncertainty normally associated with large and untried technological ventures is compounded by difficult social and political questions. The key financial issue stems from this uncertainty--how shall the risk that actual custodianship and disposal costs might exceed planned costs be borne?

THE STRUCTURE OF THE PAPER

This paper deals with the financial risks associated with the disposal of radioactive waste from commercial power plants. Chapter II describes the cost elements that are central to this risk, and Chapter III analyzes how the correct generating fee changes with variations in these cost elements. Finally, Chapter IV assesses four ways of dealing with this uncertainty: assigning it to current electricity consumers, future consumers, the government, or those private investors willing to assume the risk.

CHAPTER II. THE SIZE AND SCOPE OF THE WASTE DISPOSAL PROGRAM

Various legislative proposals and Administration plans have prompted different definitions of a radioactive waste disposal program. In order to provide a standard basis for the analysis in Chapter III, this chapter defines the proposed Department of Energy (DOE) radioactive waste program, discusses possible additions to that program, and provides cost estimates for individual program elements.

ELEMENTS OF THE NUCLEAR WASTE DISPOSAL PROGRAM

Program Definition

According to the DOE program schedule and estimates of the demand for repository services, the repository program would span 44 years--from the research and development activity now underway to the decommissioning of the second repository in 2025.[1] According to this schedule, construction for the first geological repository would commence in 1987, and the facility would be available for waste loading in 1994.[2] Construction for the second repository would begin in 1992, and it would begin receiving spent fuel in 1999. DOE projects that both would be filled and decommissioned by 2025. These dates, however, are uncertain, and scheduling might be delayed for a variety of reasons. A suitable site might prove difficult to locate, both for technical reasons and because of local opposition to the facility. In addition, as will be seen in Chapter III, nuclear generating capacity growth might be sufficiently low so that the construction of a second repository could be delayed.

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1. According to current requirements of the Nuclear Regulatory Commission, the repository would remain open for 50 years, or until 2052 under the current DOE schedule for opening the repository in 2002.

2. The schedule was in effect during the writing of this analysis. The current DOE schedule would open the first repository in 1997 and the second in 2002. Delaying the opening of both repositories, however, does not have a significant effect on the outcome of this analysis if construction costs rise no more than the rate of inflation. The stretchout in construction costs would lower the optimal fee by about 5.5 percent.

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The several activities of the DOE radioactive waste disposal program fall into two groups: "common cost" elements and "repository-specific" elements. Common cost elements are those whose costs are common to all potential repository sites, that is, they do not depend on the actual geologic medium in which the repository is built. These include research and development, site evaluation and selection, and construction of a small-scale test facility. Repository-specific elements are those whose costs depend on the nature of the repository medium. These include the construction of the repository, its operation and maintenance, payments to state and local governments that house the repository, and its final decommissioning, that is, sealing the repository once it is full.

Possible Additions to the Program

Some proposals have added other elements to the definition of a waste disposal program. The first of these is a facility for storing spent fuel on an interim basis, usually termed an away-from-reactor storage facility, or AFR. An AFR might be necessary as an interim storage facility to accommodate spent fuel for those power reactors which have exhausted their on-site storage capabilities. Current DOE estimates indicate that 29 nuclear units will require additional storage capacity between 1986 and 1990. This breaks down into seven units in 1986, six in 1987, five in 1988, ten in 1989, and one unit in 1990. If utilities are limited in their ability to increase on-site storage capacities, some may run out of storage space by 1985. On the other hand, if transshipment is allowed, along with other on-site storage enhancement methods, storage exhaustion could be delayed until 1988 or 1989. In any event, it is unlikely that a repository will be operating before 1994, and hence an AFR could become necessary. It is by no means clear, however, that the federal government would have to provide interim storage services. Indeed, the construction and financing of an AFR facility is entirely separate from the construction and financing of the final geologic repository in all current legislative proposals. Following this practice, this analysis does not investigate the implications of including an AFR in the waste disposal program.

A second potential addition to the federal program could be a Monitored Retrievable Storage (MRS) facility. A MRS might be required as an interim measure (perhaps for 100 years) in the event of significant delays in the repository program. It could also allow the uranium and plutonium fuels contained in the spent fuel assemblies to be recovered and put to use should that become economic. This latter point is cited by both proponents and critics of the MRS. Proponents, concerned with the long-run availability of energy, point out the value of preserving the fuel use option. Critics cite the availability of the fuel as a long-term temptation for misuse or theft of the nuclear materials for illegal weapons production.

The MRS facility considered in this analysis would be a small one, with a 2,800 metric ton capacity. The facility is assumed to be filled, while the first repository is under construction, and then unloaded when the repository is ready in 1994. Thus it would function as a warehouse and backup storage facility in case the repository program was delayed.

Other proposals, not considered in this analysis, have envisioned a much broader concept for the MRS--namely that spent fuel remain in several 48,000 metric ton MRS facilities for up to 100 years while further research is conducted to determine optimal sites for the first two repositories. This strategy would also allow for reprocessing of the spent fuel if it eventually proved economic. The cost for this broader MRS concept would be much larger than for the limited role assumed here. One study estimates a 48,000 metric ton facility would cost $2.4 billion (in fiscal year 1981 dollars).[3]

The implications of using the MRS to postpone final disposal reach well beyond its cost. Such a strategy would introduce much larger uncertainty into the final disposal costs than would the current program, because the information gained from actual repository experience would be so long delayed. Not only would this increase the chance of error in the fee estimate, but it would also make retrospective collection impossible because the size of any error would not be known until well beyond the probable lifetime of the nuclear plants themselves.

In any event, this analysis confines itself to assessing the financial impact of a small MRS facility, with total costs of $508 million (in fiscal year 1982 dollars). Clearly, a much larger MRS facility would have a greater impact on the optimal fee across all four nuclear-power growth scenarios, which are discussed in Chapter III.

A final addition concerns transportation from reactor sites to the repository or perhaps to an AFR. This is currently assumed to be the responsibility of the individual utilities, but could be included in the formal definition of the federal repository program, if the regulatory treatment of waste transportation precluded private sector shipment of spent fuel. This could make the federal government responsible for the assumption and recoupment of these costs. Indeed, the current Senate legislation, S. 1662, includes transportation in the waste disposal program trust fund.

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3. Department of Energy, Office of Nuclear Waste Management and Fuel Cycle Programs, The Monitored Retrievable Storage Concept (December 1981).

COSTS OF THE PROGRAM

According to the DOE, a program leading to two geological repositories, one operational in 1994 and the other in 1999, would cost about $14.8 billion (expressed in fiscal year 1982 dollars, as are all estimates given in this report unless otherwise noted). Of this total, $4.1 billion would be spent on common cost elements and $10.7 billion on repository-specific elements.

Common Cost Elements

Common costs include research and development and site evaluation. The largest of these is research and development. This is estimated to cost $2.2 billion, or over 13 percent of total program costs and about 50 percent of total common costs. The bulk of these costs is anticipated to be spent during the first ten years of the program's life, averaging over $130 million annually in constant fiscal year 1982 dollars.

The second largest common cost is the exploration and evaluation of candidate repository sites. Current proposals call for development of at least three candidates from which each repository site is to be chosen. The DOE estimates that these costs will be about $1.5 billion (or over 10 percent of total program costs and over 35 percent of total common costs). Since these costs are set by the repository schedule, most will be incurred during the first eight years of the program, averaging over $140 million per year.

The third common cost element is the test and evaluation facility. This facility may or may not be located at a potential repository site, and therefore, can be considered separately from the repository. In any event, this facility could be crucial in assessing the proper site for the actual repositories. Cost estimates for the test and evaluation facility are $300 million. These costs would be incurred during the program's early years, during which over 90 percent (or $290 million) would be spent from fiscal years 1984 to 1990.

Repository-Specific Costs

The two repositories account for $10.3 billion of the estimated program cost of $14.8 billion. The most suitable geological formations in which to build these facilities have not been decided, but candidates include salt, basalt, granite, or volcanic ash. Thus, current estimates are "generic" ones, wherein a composite cost is derived from average cost assessments of each of the various media. Consequently, considerable variation from these estimates may in fact occur as further information is gathered. DOE estimates the capital cost of each generic repository to be about $1.1 billion, yielding a total capital cost estimate of $2.2 billion. Once constructed, the repositories would incur operation and maintenance costs accounting for the remaining $8.1 billion. These costs are composed of fixed and variable elements. The fixed element represents the overhead costs of each facility and is estimated at $38 million annually (in fiscal year 1982 dollars). The variable element is dependent upon the fill rate at which nuclear waste is delivered to the repository, but ranges around $100 million per year.

Payments to state and local governments for locally incurred costs related to siting and repository construction and possible risks of accidents are estimated to total about $400 million. Much of the cost would occur relatively early in the program when repository sites are being chosen. There is considerable uncertainty about the timing and magnitude of these payments, however.

Costs of Potential Additional Elements

The cost elements discussed thus far are absolutely essential to any waste disposal program. In addition, three other cost elements could be added to the program: a MRS facility and federal assumption of responsibility for the transportation of the spent fuel. The total cost of a MRS facility is estimated at $508 million. Construction and container costs would be about $240 million, and operating and licensing costs would account for about $270 million. Transportation costs would total $4.9 billion for filling both 68,000 metric ton repositories.

CHAPTER III. FUNDING THE NUCLEAR WASTE DISPOSAL PROGRAM THROUGH A GENERATION FEE

This chapter examines a generation fee designed to finance the radioactive waste disposal program. Its underlying premise is that the users of the program--ultimately, consumers of nuclear-generated electricity--should pay its costs in direct proportion to their use. A fee to achieve this could be imposed at any of several points in the nuclear fuel cycle--at uranium fuel fabrication, at nuclear-powered electricity generation, or when spent nuclear fuel actually is delivered to the repositories. Recent legislative proposals have prescribed a fee assessed at the point of electricity generation; the analysis in this chapter, therefore, emphasizes that approach. The level of a generation fee required to pay for the waste disposal program is then examined under a variety of assumptions about program cost, program definition, and growth of nuclear capacity.

Under these various assumptions, the required generation fee to effect a self-financing program ranges between 0.5 and 0.6 mills per kilowatt hour in fiscal year 1982 dollars. The fee would increase substantially only if the waste repository program incurred significant cost overruns. But with this exception, the fee level required to finance the entire repository program would be fairly stable over a broad range of assumptions concerning nuclear capacity growth and waste program definitions.

THE NATURE OF A SELF-FINANCING RADIOACTIVE WASTE DISPOSAL PROGRAM

A radioactive waste disposal program would be self-financing if the fees assessed on the generation of waste were adequate to pay for the costs of disposing of it. The program defined in this paper is the current DOE plan to construct two geologic repositories with a combined capacity to bury 136,000 metric tons of radioactive waste. The disposal program would be self-financing, therefore, if the fees collected in conjunction with the generation of this amount of waste were equal to the ultimate costs of the entire program associated with the construction of the two repositories.

For purposes of this analysis, the basic repository program includes common costs (technological development, site evaluation and preparation, and, a separate test and evaluation facility) and site-specific costs (construction of two repositories, operation and maintenance costs for the two repositories, the costs of closing and sealing the filled repositories and payments to state and local governments). Additions to this basic program--federal transportation of the spent fuel and construction and operation of a Monitored Retrievable Storage facility (MRS)--are discussed later in this chapter.

Establishing the Generation Fee

The program would be financed through a generation fee assessed on each kilowatt hour of nuclear electricity produced in the United States, since this energy would be the source of all the radioactive waste deposited in the repositories. Defense wastes are not included in the analysis of this program; however, their inclusion would present no problem of cross-subsidies as long as the full pro-rata share of the program's costs were borne by the government.

One way to make the repository program self-financing would be to calculate the annual program costs as they are expended and to divide them by the number of kilowatt hours of electricity generated in that year. The problem with this approach is that the schedule of annual program costs and annual generation fee receipts would be very different. Annual generation fee revenues would be fairly stable, since the number of nuclear reactors in operation does not change dramatically from year to year. Rather, nuclear generating capacity probably will grow to some plateau early in the next century and remain there.

By contrast, annual repository program costs would vary significantly over time. Initially the program costs generally would be large, as significant amounts were spent to provide a strong technological base for the repositories, to test and develop sites, and to construct the repositories. Once they were constructed, the annual costs of operating and maintaining the repositories would be relatively small. When the repositories are full, the final cost of sealing the repository--usually termed decommissioning--would be incurred in the program's last year.

If a fee were assessed annually to match the stream of annual costs, it would be very large at first and much smaller later in the program's life. But a fee of this nature would charge consumers of nuclear electricity in the program's early years a far higher price for the same service (the burial of the resulting radioactive waste) than would be charged to consumers of nuclear electricity in the program's later years. This would lead to an inefficient allocation of resources since nuclear-generated electricity would cost too much in the early years and too little later on. Equally important, this distribution of charges would be widely perceived as unfair, since different electricity consumers would be charged different prices for the same benefit. A self-financing program, therefore, must find some constant level of generation fee that would be sufficient to meet the program's total cost over its complete life.

Creating a Repository Trust Fund

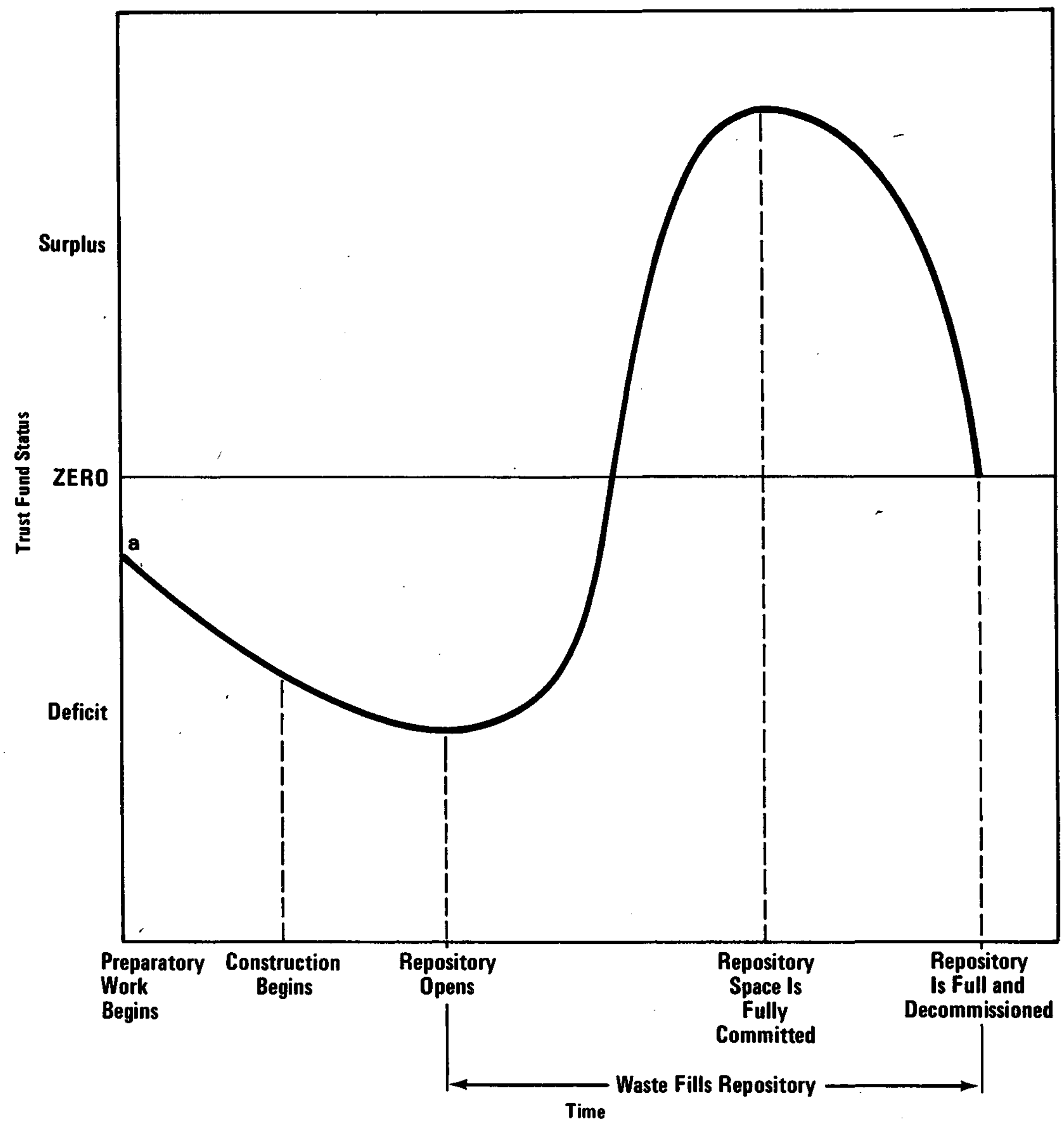
The problem of matching revenues to costs for equitable consumer charges could be resolved through use of a trust fund for the radioactive waste disposal program. The federal government would create a separate account for all of the costs associated with the two repositories, from research and testing at the beginning of the program to decommissioning at the end. The trust fund would also receive all of the revenues collected through a generation fee imposed on the production of nuclear-powered electricity. If costs exceed the revenues expressly obtained to finance the project in any one year, then the trust fund would borrow on its own account to meet its obligations. The trust fund thus would be responsible for the future interest payments that such borrowing would entail. Conversely, if the trust fund ran a surplus, it would earn interest payments on this surplus--presumably by investing in government bonds.

This analysis used an interest rate (both for borrowing and investing) equal to the rate of inflation plus 4 percent. Analysis of changes in this interest rate found they were insignificant when calculating the level of generation fee needed to make the program self-financing. The rate of inflation was assumed to be 7 percent annually through 1985, and 5 percent thereafter.

Figure 1 presents the characteristic pattern of annual costs and revenues for the two-repository program. As seen in this figure, the trust fund, however the program was defined and under all assumptions, would initially run deficits because the highest annual program costs would be incurred in the early years. Once the repository was opened and began to accept waste, annual surpluses of revenues over costs would occur because of the reduction in outlays. But despite these annual surpluses, the trust fund would require several years to revert to a surplus position. This would happen because the initial years of trust fund deficits would produce a large debt that would have to be retired along with interest costs on its accumulated borrowing. Once these debts are retired, the trust fund's surplus builds, as annual surpluses accumulate and as the trust fund's surplus earns interest. These surpluses would continue until the entire repositories' space was committed to the radioactive wastes associated with electricity production on which generation fees have been paid.

Figure 1.

Status of the Trust Fund for Two-Repository Waste Disposal Program Over the Life of the Program



[a] This analysis assumes that program costs of $187 million will be incurred in fiscal year 1982, while no revenues are collected. Assuming an 11 percent interest charge on this debt, the trust fund will begin operations with a deficit of $206 million in fiscal year 1983, the year the generation fee will start to produce revenues.

These annual surpluses would cease once the last batch of nuclear fuel committed to the repository was withdrawn from the reactor. At that point, the surplus of the trust fund, and the interest it would subsequently earn, would have to be large enough to cover all the remaining costs of the program--both the remaining operations and maintenance costs, and the costs of final decommissioning. If the fee had been set at the correct level, it would leave a surplus large enough to cover all of these final costs and perfectly expend itself. Once the last dollar of program costs has been spent, the trust fund should have a value of zero.

Thus, the calculation of an ideal generation fee that would cover total program costs is complicated, but unambiguous--as long as program definition and costs do not change. The fee must be set so as to build a trust fund surplus in the later years of the program sufficient to retire the program's initial debts and still leave enough of a surplus to cover the costs of the program once revenue collections cease. It must pay for interest charges when the trust fund is in deficit as well as actual program costs. It must allow for interest earned when in surplus. And in order to charge current and future consumers of nuclear-powered electricity the same price for the equal benefits they receive, the fee must have a constant real level, corrected for inflation only.

For the purposes of this analysis, a constant real fee that meets these requirements is termed an "optimal" fee. In a certain world, the level of this fee could be calculated unambiguously. In the real world, the level of the optimal fee would vary with underlying assumptions regarding program costs, the timing of program costs, and the number of nuclear reactors in operation at any time. The following section addresses these sources of sensitivity.

REVENUE SUFFICIENCY OF THE GENERATION FEE

This section provides estimates of the generation fee level required to make the radioactive waste repository program self-financing. This optimal fee, however, would change as underlying assumptions change. The three assumptions that would most significantly influence the optimal fee are:

- The Level of Nuclear Generating Capacity. If a lower rate of growth of nuclear generating capacity is assumed, then the level of the optimal fee would increase.

- The Definition of the Radioactive Waste Program. If other elements are added to the radioactive waste program, most notably the addition of a Monitored Retrievable Storage Facility or assumption of responsibility for transporting radioactive wastes from generation stations to the repository, then the level of the optimal fee would rise.

- Changes in the Cost of the Program. If the waste disposal program experiences cost overruns, as are common to first-time projects of this type, then the level of the optimal fee would increase.

Sensitivity to Nuclear Capacity Growth

The optimal fee is not highly sensitive to variations in the assumed growth of nuclear generating capacity. But in general, a lower rate of nuclear capacity growth would result in a higher value for the optimal fee. This relationship occurs for two reasons. First, with a lower rate of capacity growth, fewer reactors will be paying generation fees into the program trust fund. This would result in lower initial revenues, despite the fact that the revenue per kilowatt hour is higher; and, because revenues are lower early in the program while high early costs are fixed, the trust fund deficit would become larger. This, in turn, would lead to higher financing charges.

Second, with a lower rate of nuclear capacity growth, it would take longer to fill a repository. This would add additional years of operation and maintenance costs--which are only incurred after the repository is opened--to the program's total costs. Yet despite these effects, radically different assumptions regarding nuclear capacity growth do not lead to radically different levels of the optimal fee.

This analysis employs four different assumptions about nuclear capacity growth, as follows:

- High-Growth Case. Under the high-growth case, nuclear generating capacity grows from 109 gigawatts in 1985 to 188 gigawatts in 1995, and reaches a steady state of 250 gigawatts in the year 2004. This growth is sufficient to commit fully the first repository's space by 1998, and the second's by 2009. These fill rates are consistent with the announced schedule of the DOE program.

- Medium-Growth Case. Under the medium-growth case, nuclear generating capacity grows from 96 gigawatts in 1985 to 145 gigawatts in 1995, and reaches a steady state of 200 gigawatts in 2005. This growth is sufficient to commit fully the first repository by 2000 and the second by 2014. These fill rates are also consistent with the announced DOE program schedule.

- o Low-Growth Case. Under the low-growth case, nuclear generating capacity grows from 82 gigawatts in 1985 to a steady state of 120 gigawatts in 1995. Under this case, the first repository is fully committed in 2005 and the second in 2026. This fill rate calls for modifications of the DOE program, which plans to decommission the second repository in 2024. If the second repository's space is claimed by 2026, it could not be decommissioned until 2043.

- o Very Low-Growth Case. Under the very low-growth case, nuclear generating capacity grows from 70 gigawatts in 1985 to a steady state of 100 gigawatts by 1995. Under this case, space in the first repository is fully committed in 2012, and space in the second is fully committed by 2039. Again, these fill rates require extension of the DOE program timetable, so that the second repository's decommissioning would be delayed from 2024 to 2048.

These nuclear-growth scenarios are summarized in Table 1.

TABLE 1. ALTERNATIVE NUCLEAR CAPACITY GROWTH RATES (By calendar year, in gigawatts)

	1985	1990	1995	2000	2010
High Nuclear Growth	109	144	188	230	250[a]
Medium Nuclear Growth	96	128	145	175	200[b]
Low Nuclear Growth	82	115	120[c]	120	120
Very Low Nuclear Growth	70	90	100[d]	100	100

a. Steady state of 250 gigawatts reached in 2004.
b. Steady state of 200 gigawatts reached in 2005.
c. Steady state of 120 gigawatts reached in 1995.
d. Steady state of 100 gigawatts reached in 1995.

In current dollars, changes in assumptions about nuclear capacity growth would result in sizable differences in both project costs and financing costs (the interest earned and paid out by the trust fund). But when these costs are corrected for inflation, the differences prove to be small. Project costs, financing costs, and the level of the optimal fee for each of the four nuclear capacity growth assumptions are presented in Table 2. When expressed in current dollars, total project costs under the

TABLE 2. OPTIMAL FEES AND TOTAL PROGRAM COSTS, UNDER FOUR NUCLEAR CAPACITY GROWTH RATES

	High Growth	Medium Growth	Low Growth	Very Low Growth
Optimal Fee (In mills per kilowatt hour; in fiscal year 1982 dollars)	.483	.517	.549	.570
Total Program Costs (In billions of current dollars)	47.8	47.8	86.2	98.5
Total Program Costs (In billions of fiscal year 1982 dollars)	14.8	14.8	15.9	15.9
Total Financing Costs (In billions of current dollars)	-15.6	-8.4	-27.4	2.9
Total Financing Costs (In billions of fiscal year 1982 dollars)	-1.2	-0.3	-0.2	1.7

very low-growth case would be double those of the high-growth case. But this difference occurs because of the length of time needed to fill the repositories under the very low case; it takes an additional 24 years to fill and decommission the repositories under this case than it does under the high-capacity case. Thus, the costs incurred in the additional 24 years would be subject to an additional 24 years of inflation. When corrected for inflation, this difference narrows, with low-growth program costs only marginally higher than high-growth costs ($15.9 billion for the two lowest-growth cases versus $14.8 billion for the two highest-growth cases). This slight difference occurs because waste is delivered at a lower rate under the low- and very low-growth cases. Since the repository must remain open longer to be filled, it would incur additional years of operation and maintenance costs.

Similarly, the total financing costs, when expressed in current dollars, would vary widely with different assumptions about nuclear capacity growth rates. In current dollars, no direct relationship exists between financing costs and the growth rates of nuclear capacity, because of the timing of annual deficits and surpluses in the trust fund. For example, current dollar financing costs would be greater for the low nuclear-growth case than for either the medium or very low cases. They would be higher than under the medium case because the trust fund would build its surplus later, and, therefore, earn inflated dollars. They would be higher than under the very low case because the very low case would build a deeper deficit early in the program. Thus, many different factors would affect the net earnings or payments realized by the trust fund, if expressed in current dollars.

When corrected for inflation, these differences shrink dramatically and a clear relationship emerges. Under the high-growth case, the trust fund would earn more in interest when it is in surplus than it would pay out when it is in deficit. Thus, it would earn a net $1.2 billion in interest charges, and this $1.2 billion would become available to defray total program costs. These inflation-corrected net earnings would shrink to $0.3 billion under the medium-growth case and to $0.2 billion under the low-growth case. Under the very low-growth case, net interest payments would occur at a real level of $1.7 billion; these interest costs must be added to actual program costs and like the program costs, must be recouped through the generation fee. Interest costs would be lower (in fact, earnings increase) as capacity growth increases in general, because the greater revenue base provided by high, early nuclear capacity would lead to smaller initial deficits. These smaller initial deficits would then lead to smaller interest payments, and allow the trust fund to achieve a surplus position more rapidly.

Thus, when both program and financing costs are corrected for inflation, the differences among the four nuclear-growth cases shrink dramatically. The optimal fee under the high-growth case would be .483 mills per kilowatt hour in fiscal year 1982 dollars; and, like all other fees described here, it would need to be corrected continually for inflation in actual practice. Under the medium-growth case, the optimal fee would rise to .517 mills per kilowatt hour. Under the low- and very low-growth cases, the fee would increase to .549 mills and .570 mills, respectively. While these fee levels may differ by up to 20 percent, all of them are about equal to 1 percent of the (inflation-corrected) cost of nuclear-generated electricity over the life of the program. These differences are not large when viewed from the perspective of total electricity costs. The actual payments made by electricity consumers would be less than 1 percent of the cost of nuclear-powered electricity, since most electricity consumers receive electricity from a variety of sources. Thus, the waste disposal program should not result in appreciable increased changes to electricity consumers.

Sensitivity to Program Definition

Defining the disposal program to include elements not contained in the one proposed by DOE and analyzed here also could lead to variance in the optimal fee. Specifically, the inclusion of waste transportation costs or the addition of a small Monitored Retrievable Storage (MRS) system, costing about $500 million, would increase the optimal generation fees somewhat. Adding an MRS facility would raise the optimal generation fee under each nuclear-growth scenario by approximately 5 percent. Inclusion of waste transportation costs would add about 20 percent to these optimal fee levels. But all of these fee levels would still represent only 1 percent of the cost of nuclear-powered electricity.

The results of these additions are summarized in Tables 3 and 4. Table 3 presents optimal fee levels when transportation costs are included. As discussed in Chapter II, the inclusion of transportation costs would increase total program costs by about $4.9 billion. Financing costs, however, would fall if transportation costs were added (or, conversely, financing earnings rise), because transportation costs are incurred in the later part of the program's life. Thus, when the optimal fee is increased to cover transportation costs, a smaller deficit would occur in the early part of the program. This would allow the trust fund surplus to build more rapidly, and lower the total interest payments to be paid on the trust fund's initial deficit.

TABLE 3. OPTIMAL FEES AND TOTAL PROGRAM COSTS WITH TRANSPORTATION COSTS INCLUDED, UNDER FOUR NUCLEAR CAPACITY GROWTH RATES

	High Growth	Medium Growth	Low Growth	Very Low Growth
Optimal Fee (In mills per kilowatt hour; in fiscal year 1982 dollars)	.592	.633	.664	.669
Total Program Costs (In billions of current dollars)	68.4	68.4	113.1	141.9
Total Program Costs (In billions of fiscal year 1982 dollars)	19.7	19.7	20.8	20.8
Total Financing Costs (In billions of current dollars)	-28.9	-20.1	-42.1	-23.0
Total Financing Costs (In billions of fiscal year 1982 dollars)	-3.0	-1.8	-1.8	0.0

TABLE 4. OPTIMAL FEES AND TOTAL PROGRAM COSTS WITH A SMALL MONITORED RETRIEVABLE STORAGE FACILITY INCLUDED, UNDER FOUR NUCLEAR CAPACITY GROWTH RATES

	High Growth	Medium Growth	Low Growth	Very Low Growth
Optimal Fee (In mills per kilowatt hour; in fiscal year 1982 dollars)	.506	.541	.577	.600
Total Program Costs (In billions of current dollars)	48.6	48.6	86.9	99.2
Total Program Costs (In billions of fiscal year 1982 dollars)	15.3	15.3	16.4	16.4
Total Financing Costs (In billions of current dollars)	-14.8	-7.3	-25.2	7.5
Total Financing Costs (In billions of fiscal year 1982 dollars)	-1.0	0.0	0.0	2.1

When these changes for including transportation in program costs are taken into account, the optimal fees for each nuclear-growth scenario can be recalculated. For the high, medium, low, and very low nuclear-growth cases, the resulting levels of optimal fees increase to .592, .633, .664, and .669 mills per kilowatt hour, respectively (again, in fiscal year 1982 dollars). These fees would be 20 percent higher than those needed to finance the program without transportation costs.

Table 4 presents fee estimates for a program with a Monitored Retrievable Storage system. As discussed in Chapter II, the inclusion of a MRS in the waste disposal program would raise total real program costs slightly by $0.5 billion under all nuclear-growth cases. Unlike the inclusion of transportation costs, however, the addition of a MRS would increase total financing costs (or, conversely, lower financing earnings). This would happen because the MRS costs would occur during the early stages of the program's life, thus increasing the initial trust fund deficit, with associated higher interest payments, and deferring the trust fund's transition to surplus. The optimal generation fee under the four nuclear-growth cases--high, medium, low, and very low--would rise to .506, .541, .577, and .600 mills per kilowatt hour, respectively. This would represent an increase of 4 to 5 percent over fee levels calculated without the MRS facility.

Sensitivity to Cost Overruns

Cost uncertainty provides the dominant financial risk for the radioactive waste disposal program. The level of optimal fee is significantly more sensitive to cost overruns than to changes in nuclear capacity growth or in program definition. This extreme sensitivity occurs because the cost estimates, which are made during the early stage of this new and untested program, can escalate rapidly as the program development proves to be much more expensive than the original estimates. Indeed, historical analyses suggest that the actual costs of technology-intensive pioneer plants usually exceed early estimates by a large amount.

Several individual estimates appear important as potential sources of error in the current cost estimates. First, the current estimates of repository costs are generic ones, representing the weighted average of the three most attractive geological formations for repository placement. The actual site-specific costs would almost certainly be different. Second, the regulatory requirements, which the disposal program must meet, are not yet firm. Unexpected changes in them could significantly affect costs and site availability. Third, the actual level of payments to state and local governments might diverge widely from the currently anticipated $440 million (in fiscal year 1980 dollars). Finally, technological difficulties not yet anticipated could significantly alter the costs and accomplishments of the program. None of these possible misestimates mean that cost overruns would necessarily happen. They simply call attention to historical experience, which is replete with unexpected cost increases that comprise a significant financial risk.

In two recent studies, the Rand and Mitre Corporations have analyzed relevant experiences regarding cost overruns.[1] The Rand study utilized data on 44 commercial-scale process plants that involved some type of new plant design. Three overrun factors--inaccurate inflation projections, unanticipated regulatory changes, and other unforeseeable events were found to account for only 26 percent of the total cost misestimation in the sample.

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1. Merrow, Phillips, and Myers, Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants (The Rand Corporation, September 1981); and The Mitre Corporation, Analysis of Nuclear Waste Disposal and Strategies for Facilities Deployment (April 1980).

The greater bulk of unanticipated capital cost growth was attributed to a lack of information at early stages of engineering. Many cost elements, Rand concluded, cannot be estimated during the early period of a project because of an inadequate information base. Thus, normal engineering-based estimation techniques cannot anticipate this source of cost overruns. Specifically, the study examined the ratio of estimated to actual costs for cost estimates made at the five stages of the development cycle of a new project--research and development, project definition, engineering, construction, and start-up. Cost estimates were made throughout this development cycle. The Rand study concluded that the ratio of estimated to actual costs rose from .49 during the research and development phase to .93 in the start-up phase. Thus, cost estimates improved as projects developed.

The nuclear waste disposal program is now between the research and development stage and the project definition stage. At the research and development stage, conceptual cost estimates are provided while basic theoretical knowledge of the new process is gathered. This applies to the nuclear waste disposal program, since basic research and development is currently underway to assess the appropriate medium in which to locate the repositories. On the other hand, parts of the program appear to have advanced into the next stage of project definition, in which the scope of the program is defined. In the Rand study, the average ratio of estimated to actual costs at this definition stage was .62 in contrast to the .49 ratio for the research and development stage. Thus, probable capital costs are 67 percent greater than estimated at this stage. This number was used in this analysis to approximate the cost overruns that might be experienced in actual repository construction. Such overruns would increase the cost of constructing the two repositories from $2.27 billion to $3.79 billion. (If the estimates from the research and development stage were employed, cost overruns would average 104 percent, increasing construction costs from $2.27 billion to $4.63 billion.)

Since the Rand study considered only capital cost overruns, this report needed to examine other sources of cost overruns in the program. The Mitre study was appropriate for this task. Mitre estimated possible cost overruns at each stage of the waste disposal program by examining the number of sites requiring investigation at each stage to ensure the selection and operation of at least one repository site. Its estimates were based on a survey of engineers, who were asked to respond to hypothetical circumstances regarding the disposal program. A cost estimate was considered an upper bound if that level of cost resulted in a 99 percent probability of locating a site. It was assumed that most of the information required to determine an appropriate site was obtained from more advanced surface testing, on-site testing, or construction, rather than from more preliminary site screening. Thus, these upper bounds may be slightly understated.

The Mitre study determined the number of sites that would have to be considered to obtain a 99 percent probability of finding an acceptable candidate. It concluded that, under the worst case, 34 to 35 sites would have to be considered at the site-screening stage, compared to two to three sites under the best circumstances. This means that worst-case site exploration and evaluation costs would be 11.25 to 17 times the best-case estimated cost. This number of required sites would decrease to 12 or 13 during the next stage of on-site testing, contrasted to one site under the best case. This translates into test and evaluation costs 12 times in excess of estimated costs under a worst-case scenario. Upon entering the next stage of actual construction, Mitre estimated that five sites would require at least some construction work to identify one satisfactory site. Actual construction costs, therefore, would be up to five times as much as anticipated costs if the worst case prevailed. During the operation phase, two facilities would have to be actually operating before one is finally considered appropriate. Thus, operation costs could be twice those estimated.

From the worst case examined in the Mitre study and from the results of the Rand study, a plausible worst-case cost overrun can be fashioned. Site exploration and evaluation costs were increased 11.25-fold, from $1.5 billion to $16.9 billion, following Mitre. Test and evaluation costs increased 12-fold (again, following Mitre) from $300 million to $3.6 billion. The research and development costs, along with payments to state and local governments, might also be subject to overruns. Since neither report considered these, however, they were held at $2.2 billion. As discussed above, the repository costs were increased 67 percent to $3.8 billion, paralleling the Rand results (but a much lower figure than the Mitre study's five-fold increase). Estimated repository operating costs were increased 50 percent, from $8.0 billion to $12.1 billion, as the two-fold increase of the Mitre study was considered excessive. Compared to the DOE base-case costs of $14.8 billion, these worst-case costs together would total $38.5 billion. This constitutes a 160 percent cost overrun. For simplicity, total costs in each year were multiplied by this figure rather than disaggregating the increases by the individual cost elements described above.

Once again, it should be stressed that cost overruns of this magnitude are not a certainty. But the history of comparable projects (as studied by Rand) and a survey of engineering opinions (as conducted by Mitre) indicate that this level of cost overrun cannot be ruled out.

To assess the impact of cost overruns on the optimal fee and trust fund schedule, program costs were increased across the board--first by 40 percent (a rule-of-thumb often used for overrun sensitivity) and second by 160 percent, a figure that represents the credible upper bound. These results are presented in Tables 5 and 6. With a 40 percent overrun of DOE base-case costs (see Table 5), the optimal fee across all four nuclear-growth cases would still be below one mill per kilowatt hour; the fees would be .672, .718, .764, and .792 mills per kilowatt hour for the high, medium, low, and very low cases, respectively. If base-case costs increased 160 percent (see Table 6), the optimal fee would exceed one mill across all four growth rates. The optimal fees would become 1.238, 1.324, 1.407, and 1.458 mills per kilowatt hour for the high, medium, low, and very low cases, respectively. These fee increases are directly proportional to the degree of the assumed cost overruns, since cost overruns increase all costs in tandem. Including a MRS and transportation costs would increase the optimal fee under a 160 percent cost overrun to 1.459, 1.560, 1.644, and 1.688, again in descending order of nuclear growth. These are the highest fees imagined in this study. In the worst case (1.688 mills), they would add up to 3 to 4 percent to consumer electricity bills.

TABLE 5. OPTIMAL FEES AND TOTAL PROGRAM COSTS WITH A 40 PERCENT COST OVERRUN, UNDER FOUR NUCLEAR CAPACITY GROWTH RATES

	High Growth	Medium Growth	Low Growth	Very Low Growth
Optimal Fee (In mills per kilowatt hour; in fiscal year 1982 dollars)	.672	.718	.764	.792
Total Program Costs (In billions of current dollars)	66.9	66.9	120.7	137.8
Total Program Costs (In billions of fiscal year 1982 dollars)	20.7	20.7	22.3	22.2
Total Financing Costs (In billions of current dollars)	-22.1	-12.1	-39.0	3.0
Total Financing Costs (In billions of fiscal year 1982 dollars)	-1.8	-0.5	-0.5	2.2

TABLE 6. OPTIMAL FEES AND TOTAL PROGRAM COSTS WITH A 160 PERCENT COST OVERRUN, UNDER FOUR NUCLEAR CAPACITY GROWTH RATES

	High Growth	Medium Growth	Low Growth	Very Low Growth
Optimal Fee (In mills per kilowatt hour; in fiscal year 1982 dollars)	1.238	1.324	1.407	1.458
Total Program Costs (In billions of current dollars)	124.3	124.3	224.0	256.0
Total Program Costs (In billions of fiscal year 1982 dollars)	38.5	38.5	41.3	41.3
Total Financing Costs (In billions of current dollars)	-41.7	-23.3	-73.6	3.4
Total Financing Costs (In billions of fiscal year 1982 dollars)	-3.6	-1.2	-1.2	3.7

ALTERNATIVES TO THE GENERATION FEE

Following the major legislative proposals to finance the waste disposal program, this analysis has concentrated on the characteristics of a constant dollar generation fee. Since Public Utility Commissions allow electric utilities to earn revenues as they generate power, it would be relatively simple to build the generation fee into the administrative structure that governs utility revenues. But alternatives to this type of fee exist.

One option would be to assess utilities a fee based on the weight of the waste that they generate. For each type of reactor, the relationship between the number of kilowatt hours a nuclear plant generates and the weight of the resulting waste is fairly constant. Thus, a weight-based fee is tantamount to a generation fee in virtually all respects, particularly since it poses the same risks related to cost overrun, program definition, and rates of nuclear capacity growth.

A second option would be to charge utilities for waste disposal services on a time-of-delivery basis. Since this payment presumably would be based on the weight of the waste delivered, it would resemble both the weight-based fee and the generation fee, again particularly since it poses the same kinds of risk. It should be noted, however, that charging utilities (and, in turn, their consumers) at the time-of-delivery, rather than at the moment of generation, means deferring any and all program revenues by over ten years. Thus, the program trust fund would be obliged to borrow all of its up-front capital for the purposes of research and development, site selection, test facility construction, and actual repository construction. This would create a sizable initial deficit for the trust fund, and would, therefore, increase the total borrowing and interest costs associated with the program. Such a financing method would require far higher fees than those assessed at the moment of generation.

A final option would set the fee at 1.0 mills per kilowatt hour, as proposed in S. 1662. As seen in this chapter, the value of the optimal generation fee is consistently less than 1.0 mills per kilowatt hour, unless cost overruns in the range of about 100 percent or greater occur. Such a fee would produce excessive revenues under all other cases. Because of the particular mathematics of the trust fund, the value of the optimal fee could determine the percentage of inflation by which the 1.0 mill per kilowatt hour initial fee should be adjusted to produce a self-financing waste disposal program. For example, under the high-growth case and in the absence of new program additions or cost overruns, the optimal generation fee would be .483 mills per kilowatt hour. Thus, an initial fee of 1.0 mills per kilowatt hour, if adjusted for 48.3 percent of the inflation rate, would result in a trust fund value of zero once the program's last dollar has been expended and the repository's decommissioning completed. It should be noted, however, that an initial 1.0 mill per kilowatt hour fee, if partially adjusted for inflation, would violate one of the conditions for such a fee's equity. By only partially reflecting inflation, such a fee would charge current electricity users a higher price for the disposal of radioactive wastes than it would charge future users. If this intergenerational inequity is considered, the partial adjustment of a 1.0 mill per kilowatt hour fee would be less desirable than a fee set at a correct initial level and fully adjusted for inflation during the program's life.

CHAPTER IV. EVALUATING THE FEE: THE ISSUE OF RISK

Barring cost overruns or changes in the growth rate of nuclear generating capacity, the radioactive waste disposal program could be made self-financing through a generation fee that would add about 1 percent to the cost of nuclear-powered electricity. But the prospects of cost overruns or changes in the growth rate of nuclear capacity cannot be excluded; to the contrary, waste disposal program planners face substantial uncertainty regarding the costs of the repository program and the growth rate of the nuclear generating capacity that the program serves.

THE PROBLEM OF FINANCIAL RISKS

Setting the level of the generation fee necessarily entails financial risks--either that the fee would prove too low and additional revenues would have to be raised subsequently, or that it would prove too high and impose an economic burden on energy consumers. In both cases, intergenerational subsidization would occur. This chapter presents alternative approaches for dealing with the financial risk associated with the radioactive waste disposal program: assign it to current ratepayers, assign it to future ratepayers, allow the taxpayers (the federal government) to bear the risk, or allow private investors to bear the risk in exchange for the prospects of economic gain.

These alternative approaches can be evaluated in terms of economic efficiency and fairness. An economically efficient program would be conducted at its lowest possible cost, consistent with proper provision for public health and safety and for environmental protection. This would require incentives to hold down program costs, and to minimize trust fund financing costs. The second principle, that of fairness, would require matching those who consume nuclear-generated electricity with the costs of the waste that such consumption engenders, and charging current and future electricity consumers the same price for the same service.

If the real costs of the radioactive waste program deviate from the planned costs by a small amount, then the efficiency losses and equity concerns are likely to be insignificant. But the possibility, however remote, of major errors in estimating the optimal fee, raises the issue of who should bear the financial risk.

OPTIONS FOR ASSIGNING THE FINANCIAL RISK

This report examines four approaches to assigning the financial risks associated with the waste disposal program:

- Assign the Risk to Current Ratepayers. Current ratepayers would be forced to bear the risk by paying a fee higher than that calculated to be optimal, thus building into the trust fund assumptions regarding the amount of cost overrun.

- Assign the Risk to Future Ratepayers. Future ratepayers would be forced to bear the risk if an optimal generation fee were calculated using current DOE base-case cost estimates and these estimates later proved to be wrong and had to be adjusted upward.

- Assign the Risk to the Federal Government. The government could bear the risk by promising to meet any costs above those anticipated at the beginning of the program or some other announced level.

- Assign the Risk to the Private Sector. A federal corporation could be chartered and licensed by the Nuclear Regulatory Commission to construct and operate the waste disposal facility. In return for its profit, it would assume responsibility for any cost overruns or other unanticipated financial difficulties with the program.

Assign the Risk to Current Ratepayers

Two arguments can be made for setting the initial fee at a level higher than that warranted by the best current cost estimates. First, experience has shown such early estimates consistently are understated. A higher initial fee would simply ratify that experience. Second, it can be argued that present electricity users have created the demand for nuclear power plants and have borne the other financial risks of nuclear power. Therefore, these present electricity users should also bear the financial risks of disposing of its wastes.

Three objections may be made to these arguments. First, it is not possible to know how high to raise the fee above current estimates in order to cover future unforeseen costs, and current cost estimates already include substantial margins for error. Second, the existence of a financial cushion might reduce the incentives for efficient program management, thus leading to self-fulfilling cost overruns. Third, future electricity users would also benefit from the same nuclear power plants paid for by the current generation of consumers.

If the risk of cost overruns were assigned to current ratepayers by setting a higher fee, but the risk did not materialize, how would the optimal fees change? Table 7 presents estimates of the optimal fees under these circumstances. These estimates assume that an initial fee of 1.0 mills per kilowatt hour (adjusted for inflation) was set, but that the DOE base-case costs were not exceeded. After seven years of program life, planners would realize that the base-case costs were realistic, and that the generation fee could be reduced to a level that would be considered optimal over the balance of the program's life. The optimal fee for the balance of the program's life would decline by about 50 percent from the original optimal fee level set by the DOE base-case costs. Thus, early electricity consumers would subsidize later ones. The value of this subsidy can be estimated by examining total financing costs. By creating an initial surplus in the trust

TABLE 7. OPTIMAL FEES AND FINANCIAL COSTS, ASSUMING A FEE OF 1.0 MILLS PER KILOWATT HOUR FOR THE FIRST SEVEN YEARS OF PROGRAM LIFE AND DOE BASE-CASE PROGRAM COSTS, UNDER FOUR NUCLEAR CAPACITY GROWTH RATES (In fiscal year 1982 dollars)

	High Growth	Medium Growth	Low Growth	Very Low Growth
Optimal Fee for Remaining Program Life (In mills per kilowatt hour)[a]	.200	.258	.301	.345
Total Trust Fund Earnings (In billions of dollars)	3.6	2.8	3.2	1.8
Base-Case Trust Fund Earnings (In billions of dollars)[b]	1.2	0.3	0.2	-1.7
Value of Subsidy to Future Ratepayers (In billions of dollars)	2.4	2.5	3.0	3.5

a. For eighth through final year.
b. From Table 2 in Chapter III.

fund, the institution of a 1.0 mill fee over the first seven years of the program would result in lower total financing costs (or greater earnings) of \$2.4 billion to \$3.5 billion (depending on the nuclear-growth rate) when compared to the DOE base-case found in Table 2 in Chapter III. Thus, if current ratepayers assumed the risk of overruns, but this risk did not materialize, they would have subsidized future ratepayers by those amounts, depending on the rate of nuclear capacity growth.

Assign the Risk to Future Ratepayers

If the waste disposal fee were set at the current optimum level--that is, in the range of .483 to .570 mills per kilowatt hour--and adjusted later if conditions warrant, then future ratepayers would bear the financial risks. The advantage of such an approach is that it makes the best use of currently available information. The disadvantage is that all the surprises that the disposal program might encounter are likely to push costs upward. Even though the program's managers cannot now discern these unexpected events --if they could, they would presumably include such events in the current cost estimate--history suggests that they might indeed occur. Therefore, a fee based on the current optimum estimate might well result in an effective subsidy of present electricity users by future ones.

As was the case when risks were assigned to current ratepayers, there would be a cost and subsidy involved if the risks were assigned to future ratepayers. Table 8 presents optimal fees in the event of a 160 percent cost overrun. These fees were calculated under the assumption that planners know that such overruns would occur, and that fees were initially set to accommodate them. Table 8 calculates optimal fees under the assumption that 160 percent cost overruns would occur from the beginning of the program, but that the generation fee was not adjusted to reflect them until seven years of the program have transpired. The fees in Table 8, therefore, are charged during the eighth through last years of the program. When compared to Table 6 in Chapter III, it can be seen that these fees are about 33 percent higher during the latter program period than the fees that would have been set had cost overruns been perfectly anticipated.

By not anticipating the degree of cost overruns when setting the fees' initial levels, current ratepayers would be subsidized by future ratepayers. The value of this subsidy can be estimated by observing the difference in financial costs. By deferring the increases in the generation fee that cost overruns require, the program's net financial costs increase by \$3.5 billion to \$7.3 billion, depending on the rate of nuclear capacity growth assumed. These increased financial costs must be made up by future ratepayers, and are therefore equal to the subsidy provided from future ratepayers to current ones.

TABLE 8. OPTIMAL FEES AND FINANCIAL COSTS, ASSUMING AN INITIAL FEE BASED ON DOE BASE-CASE COST ESTIMATES FOR THE FIRST SEVEN YEARS OF PROGRAM LIFE AND 160 PERCENT COST OVERRUNS, UNDER FOUR NUCLEAR CAPACITY GROWTH RATES (In fiscal year 1982 dollars)

	High Growth	Medium Growth	Low Growth	Very Low Growth
Optimal Fee for Remaining Program Life (In mills per kilowatt hour)[a]	1.652	1.756	1.879	1.922
Total Trust Fund Earnings (In billions of dollars)	0.1	-3.0	-4.5	-11.0
Base-Case Trust Fund Earnings (In billions of dollars)[b]	3.6	1.2	1.2	-3.7
Value of Subsidy to Future Ratepayers (In billions of dollars)	3.5	4.2	5.7	7.3

a. For eighth through final year.
b. From Table 6 in Chapter III.

The subsidy would still occur if the fee were set at a level that included an unforeseen cost increase but that level still proved too low. The figures in Table 9 were calculated under the assumption that a 1.0 mill fee (adjusted for inflation) was initially set, but that a 160 percent increase in costs would occur, rendering the 1.0 mill per kilowatt hour fee insufficient to cover program costs. After seven years, therefore, the fee would be reestimated to reflect the higher program costs and to cover the larger trust fund deficit built during the first seven years. The fee for the eighth through last year of the program is about 10 percent higher than it would have been if cost overruns had been perfectly anticipated at the onset. Total financial costs would increase by from $1.1 billion to $3.8 billion, depending on the nuclear capacity growth rate assumed. Thus, if a fee of 1.0 mills per kilowatt hour was set but 160 percent cost overruns occurred, future ratepayers would subsidize current ones by an amount within this range.

TABLE 9. OPTIMAL FEES AND FINANCIAL COSTS, ASSUMING AN INITIAL FEE OF 1.0 MILLS PER KILOWATT HOUR FOR THE FIRST SEVEN YEARS OF PROGRAM LIFE AND 160 PERCENT COST OVERRUNS, UNDER FOUR NUCLEAR CAPACITY GROWTH RATES (In fiscal year 1982 dollars)

	High Growth	Medium Growth	Low Growth	Very Low Growth
Optimal Fee for Remaining Program Life (In mills per kilowatt hour)[a]	1.369	1.497	1.630	1.697
Total Trust Fund Earnings (In billions of dollars)	2.5	-0.5	-1.5	-7.5
Base-Case Trust Fund Earnings (In billions of dollars)[b]	3.6	1.2	1.2	-3.7
Value of Subsidy to Future Ratepayers (In billions of dollars)	1.1	1.7	2.7	3.8

a. For eighth through final year.
b. From Table 6 in Chapter III.

Assign the Risk to the Federal Government

The principles of efficiency and equity suggest that the radioactive waste disposal program should be self-financing, that is, that the users of nuclear-powered electricity should pay for the disposal of the resulting radioactive wastes. Nevertheless, several rationales exist for the federal government to assume the risk that the required generation fee could increase dramatically.

First, the government as manager of the radioactive waste disposal program cannot escape some part of the responsibility for cost overruns. Indeed, requiring federal payments to defray part or all of the costs in excess of current estimates might provide an incentive for accurate cost estimates, top-management attention to the program, and strong Congressional oversight. Second, the government must bear some of the responsibility for the lack of past progress in developing the waste disposal program.

The fact that the current program is in its nascent stages partly results from the historic inability of the government to develop the program expeditiously. Third, the government might consciously wish to subsidize nuclear energy. Such subsidies are hardly new to the energy sector--for example, oil and gas exploration is currently granted tax subsidies worth over $5 billion annually. The case for nuclear subsidies would rest on its long-term value as an essentially inexhaustible energy resource (with the use of breeder reactors) and its value as a hedge against environmental crises resulting from the use of fossil fuels--for example, the buildup of carbon dioxide in the atmosphere.

Table 10 provides estimates of the government cost to guarantee to utilities some maximum value of the generation fee. These estimates assume that a 160 percent cost overrun would occur, but that the government would guarantee that the generation fee would be no greater than 1.0 mills per kilowatt hour (adjusted for inflation) or no greater than the generation fee obtained using DOE base-case costs (obtained from Table 2 in Chapter III). If either of these circumstances occurred, then the trust fund would be in deficit in the year that the second repository is decommissioned and the program terminated. The cost to the government given in Table 10 is the "present value" of this future trust fund deficit--that is, the amount the government would have to put in a bank account now to cover this deficit.

TABLE 10. PRESENT VALUE OF FEDERAL SUBSIDY TO THE RADIOACTIVE WASTE PROGRAM, UNDER 160 PERCENT COST OVERRUN (In billions of fiscal year 1982 dollars)

Nuclear-Growth Case	Government Assumes Costs in Excess of 1.0 Mills Per Kilowatt Hour	Government Assumes Costs in Excess of Optimal Generation Fee Reflecting DOE Base-Case Costs[a]
High	4.0	12.6
Medium	5.1	12.6
Low	5.7	11.8
Very Low	5.9	11.5

a. See Table 2 in Chapter III. The fees are: high growth, .483 mills per kilowatt hour; medium growth, .517; low growth, .549; very low growth, .570.

If the government imposed an initial fee of 1.0 mills per kilowatt hour but a 160 percent cost overrun occurred, then its liabilities would have a present value in the range of $4.0 billion to $5.9 billion, depending on the rate of growth of nuclear capacity (see first column of Table 10). Lower rates of growth in nuclear capacity would imply larger present values of ultimate trust fund deficits. This would occur because the "gap" between the 1.0 mill fee and the corresponding optimal fee under cost overruns would increase as generating growth decreases. The optimal fee, presuming a 160 percent cost overrun, would range from 1.238 mills per kilowatt hour under the high-growth case to 1.458 under the very low-growth case. Thus, the government's commitment to cover costs above the 1.0 mill per kilowatt level would increase as the rate of nuclear capacity growth decreased.

The second column of Table 10 presents equivalent present values if the government covered costs above the base-case optimal fee level. If 160 percent cost overruns occurred, the present value of this commitment should be in the range of $11.5 billion to $12.6 billion. But in this case, the value of the government subsidy would increase as nuclear capacity growth increased, in contrast to the 1.0 mill case. This would occur because, unlike the 1.0 mill case, the optimal fee would be proportionate to the cost overruns. Thus, the present value of the government's subsidy would depend not on the difference between the guaranteed maximum fee and the actual costs of the program, but on the time at which this difference occurred. Under the very low case, many costs would be deferred until the next century. Thus, costs in excess of the fee guaranteed by government would occur later under low-growth cases than they would under higher ones. This means that the government's "bank account" would earn interest longer, and the present value of its subsidy would be lower.

These estimates suggest that, if the government committed itself to covering costs above some level of generation fee, for whatever reason, its commitment might end up costing several billion dollars. To be sure, the figures in Table 10 depend on the worst case analyzed in this paper--a 160 percent cost overrun. The point is not to assert that this would happen; rather it is to assess the magnitude of the federal obligation if it did.

Assign the Risk to the Private Sector

The problems associated with assigning the disposal program's financial risks concern two hazards: first, that costs would be misestimated and that fees would have to be adjusted upward; and second, that no incentives would exist to minimize project costs, particularly if a trust fund surplus was planned. These difficulties suggest the possibility of assigning program management and financing to a private entity. Such a federally chartered corporation could be licensed by the Nuclear Regulatory Commission, could be provided with a monopoly franchise, and could be given authority to set rates calculated in the same fashion as the optimal fees in this report were calculated. This approach might have several advantages. If the corporation were obligated to provide its disposal service at a fixed long-term price, it would be forced to minimize costs and would effectively absorb the risks of cost overruns. Should these overruns occur, they presumably would be borne by the management and stockholders of the corporation.

Such an approach, however, would present several difficulties. First, it might be difficult to find private parties interested in providing this service. Licensing requirements would be extraordinarily rigorous, and the liabilities that such a firm would incur if a major accident occurred at the repository could be uninsurable. All of these extraordinary costs would force private investors to earn a rate of return higher than conventional entrepreneurial activity, which, in turn, would raise the fees charged to utilities for their waste disposal. Since the private sector has no experience in projects of this sort, it might be unwilling to assume the financial risks.

Finally, there is the possibility that such a corporation would fail. If it were to go bankrupt, it is likely that the federal government would have to assume responsibility for the program. Under these circumstances, the goals of private sector involvement would not be achieved, but the higher price that the private corporation would charge would have been paid until its failure. Under these circumstances, utilities would have paid more for waste disposal without realizing any of the benefits of private management over the life of the project. If the government was to assume responsibility, it would either be forced to raise the fees assessed utilities or to honor the corporation's long-term contracts with utilities, leading it to subsidize the waste disposal program. As was seen in Table 10, this subsidy could cost the government over $12 billion. One way of ensuring against this cost would be to require a substantial amount of bonding by the corporation, but this level of up-front capital commitment might make privately financed waste disposal prohibitively expensive.

APPENDIX

TECHNICAL APPENDIX: PROCEDURES USED TO CALCULATE THE GENERATION FEE

This appendix reviews the procedures used to calculate the optimal generation fee. There are three essential computations involved in this process:

- o The derivation of the annual revenue estimates;
- o The annual program costs; and
- o The annual trust fund balance.

ANNUAL REVENUES

The generation fee revenues in any particular year are estimated by multiplying the optimal fee times the number of kilowatt hours that the installed nuclear capacity is assumed to produce over that year. An average capacity factor of 60 percent is assumed for all nuclear units throughout all four growth-rate scenarios. This means each unit operates for 5,256 hours each year. The high, medium, and low nuclear growth cases were based on Department of Energy (DOE) forecasts through the year 2000. A steady state assumption was made once capacity levels reached their projected maximums; capacity additions are just sufficient to replace retired units. The very low-growth case, in which a steady state of 100 gigawatts of installed nuclear capacity is reached by 1995, was added to reflect the possibility that nuclear growth could fail to provide a large portion of electric power in the future.

The capacity estimates are supplied on a five-year basis. Nuclear capacity growth between these five-year intervals is derived by linear interpolation. For example, nuclear capacity under the high-growth case is assumed to increase from 109 gigawatts in 1985 to 144 gigawatts in 1990. This growth of 35 gigawatts is assumed to come on-line in equal increments of seven gigawatts per year over this period.

These revenues are supplemented by payments for the 8,200 metric tons of outstanding spent fuel at the end of fiscal year 1981. It is assumed that this waste will be paid for in equal increments of 1,640 metric tons annually over these five years. To do this requires conversion of the optimal fee to a metric ton equivalent. Using the same assumption of a yearly average discharge rate of 25 metric tons per gigawatt and a 60 percent capacity factor means that one metric ton of nuclear waste, on average, is produced every 210.24 gigawatt hours by a one-gigawatt nuclear plant. Thus, obtaining the equivalent equitable payment for outstanding spent fuel requires multiplying the appropriate optimal fee times .21024 to derive the appropriate metric ton equivalent fee (in millions of dollars).

ANNUAL PROGRAM COSTS

Annual program costs in any particular year are derived simply by summing together the relevant common and repository-specific elements, based on the DOE's estimates, and multiplying by the appropriate compound inflation rate for that year. Total program costs for the low- and very low-nuclear growth cases are higher than the high- and medium-growth cases. This is attributed to the longer program lives of the lower-growth cases. Again, the program lives are 19 and 24 years longer for the low- and very low-growth cases, respectively. Adjusted for inflation, however, the increase in program costs is only $1.1 billion for both the low- and very low-growth cases. This is attributable to the $44 million in annual fixed operating charges that both the low- and very low-growth cases experience for an additional 25 years. These two cases have identical program costs because the additional five-year program life of the very low-growth case occurs in the form of a five-year delay in the construction of the second repository. Understandably, there are no fixed or operating costs associated with this delay.

EQUATIONS FOR THE TRUST FUND

These revenue and cost relationships were formulated as equations to calculate trust fund values under different fee levels. The equation used to calculate annual fee revenues was specified as follows:

Equation 1.

TR_x = nuclear capacity$_x$ * 5.256 * optimal fee * compound inflation rate$_x$

where

TR_x = total revenues in year x

nuclear capacity$_x$ = installed capacity in year x in gigawatts

5.256 = the number of thousands of hours each unit operates over the year, assuming a 60 percent capacity factor optimal fee = the fee, in fiscal year 1982 mills per kilowatt hour, giving a trust fund balance of zero in the year the program terminates

compound inflation $rate_x$ = the adjustment to the optimal fee giving total revenues in current dollars for year x.

In addition, the supplemental revenues paid by existing stocks of waste were added as follows:

Equation 2.

SR_x = .21024 * optimal fee * compound inflation $rate_x$ * 1640

where

SR_x = supplemental revenues in year x

.21024 = factor that converts number of gigawatt hours to metric tons of spent fuel per nuclear unit; converts metric tons of spent fuel to a kilowatt hour fee equivalent

optimal fee = the fee, in fiscal year 1982 mills per kilowatt hour, giving a trust fund balance of zero in the year the program terminates

compound inflation $rate_x$ = the adjustment to supplemental revenues to change constant fiscal year 1982 dollars to current dollars in year x

1640 = the number of metric tons of outstanding spent fuel assumed paid for annually over fiscal years 1984-1988.

A cost equation was then specified as follows:

Equation 3.

TC_x = (common cost $elements_x$ + repository $capital_x$ + repository $operating_x$ + social economic $costs_x$) * compound inflation rate

where

TC_x = total program costs in year x

common cost $elements_x$ = technological development costs, site exploration and evaluation, test and evaluation facility costs repository $capital_x$ = the construction costs of either or both the first and second repository during year x

repository $operating_x$ = operating costs for either or both repositories incurred during year x

social economic $costs_x$ = payments to state and local governments in year x

compound inflation rate = the same inflation factor used to adjust total revenues in year x from 1982 dollars to current dollars.

With these specifications for annual costs and revenues, the status of the trust fund can be obtained for year x by the following equation:

Equation 4.

$TFBAL_x = (BAL_x + TFBAL_{x-1})$ * (1 + annual inflation rate + real interest rate)

where

BAL_x = the difference between total revenues, equations 1 and 2, and total costs, equation 3, in year x

$TFBAL_{x-1}$ = the trust fund balance outstanding from the previous year, in year x

annual inflation rate = the price level increase, either 7 percent annually through 1985, or 5 percent annually thereafter

real interest rate = the amount earned or paid out by the trust fund in excess of the inflation rate; assumed to be 4 percent throughout the relevant program life.

With an equation for trust fund balance in hand, the optimal fee is calculated through an iterative procedure. Only one value of the generation fee results in a trust fund value of zero at the end of the year in which decommissioning of the second repository occurs. This value was obtained through iteration. Different assumptions regarding nuclear capacity growth were then substituted into the revenue equation, and assumptions regarding program costs and definition were inserted into the cost equations. The generation fee yielding a trust fund value of zero in the program's final year was then recalculated.

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